ASCA/ROSAT OBSERVATIONS OF PKS 2316-423: SPECTRAL PROPERTIES OF A LOW LUMINOSITY INTERMEDIATE-TYPE BL LAC OBJECT

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ABSTRACT We present the analysis of archival data from ROSAT and ASCA of a serendipitous source PKS 2316-423. According to its featureless non-thermal radio/optical continuum, the object has been assumed as a BL Lac candidate in the literature. PKS 2316-423 was evident variable over the multiple X-ray observations. Specially, a variable high-energy tail of the synchrotron radiation is revealed. X-ray spectral analysis provided further evidence of its synchrotron-nature broad-band spectrum with steep and down-curved shape in the range of 0.1–10 keV, this is general signature of a HBL. The spectral energy distribution (SED) through radio-to-X-ray yields the synchrotron radiation peak at frequency $\nu_p = 7.3 \times 10^{15}$ Hz, with integrated luminosity of $L_{\rm syn} = 2.1 \times 10^{44}$ ergs s^{-1}, this suggest that PKS 2316-423 is a low luminosity BL Lac object with high synchrotron peak frequency. Further SED analysis suggest that PKS 2316-423 is a very low luminosity "intermediate" or high energy peaked BL Lac object. Given the unusual low luminosity, the further studies of PKS 2316-423 might give clues on the evolution properties of BL Lacs .

KEYWORDS: BL Lac objects: individual (PKS 2316-423) – X-rays: galaxies

1. INTRODUCTION

Earlier studies of BL Lac objects have shown that the systematic differences between radio and X-ray selected BL Lac objects (RBLs vs XBLs) can be just attributed to orientation differences. Moreover, BL Lac objects have been reclassified by a more accurate way "low energy" and "high energy" peaked BL Lac objects (LBLs vs HBLs) based on the peak frequency of synchrotron radiation (e.g. Giommi and Padovani 1994). In general, RBLs and XBLs tend to be LBLs and HBLs, respectively. They generally represent two distinct extremes of BL Lacs. However, recent studies from deeper and larger X-ray survey have shown that BL Lac objects tend to exhibit more homogeneous distributions of the properties (Perlman et al. 1998; Caccianiga et al. 1999; Laurent-Muehleisen et al. 1999) rather than previously disparate ones. This has resulted in important roles of intermediate BL Lac objects

(IBLs) in revealing BL Lac mysteries.

In this paper, we present the X-ray spectral analysis (ROSAT and ASCA archival data) and spectral energy distribution (SED) of PKS 2316-423, aiming at showing its intermediate-BL Lac properties. It is a southern radio source at $z = 0.0549$, and was formerly classified as a BL Lac candidate on the base of its featureless non-thermal radio/optical continuum (Crawford & Fabian 1994; Padovani & Giommi 1996). We noticed this object as it has been the brightest contaminating source to the nearby narrow-line X-ray galaxy–NGC 7582 (Xue et al. 1998) in most of its historical X-ray records.

The ROSAT(PSPC) and ASCA satellites observed this object as a serendipitous source in April 1993 and November 1994 respectively. These observations, together with the two ROSAT/HRI observations made in 1992 and 1993, could not only extend our knowledge of the source SED properties to the X-ray domain ($\lesssim 10$ keV), but also provide a good opportunity for X-ray spectroscopic studies in the range of 0.1–10 keV. Which turn out to be very important for the unambiguous classification of the source.

2. SPECTRAL ANALYSIS

No evident variations in the source count rate were detected over both observations spanning about half a day and a little more than one day. Thus time-averaged spectra from both satellites were used for Spectral analyzing.

A simple power-law model, with photon index of $\Gamma \sim 2.0$ and absorption column density at the Galactic value, gives acceptable fit to the ROSAT/PSPC data (Figure 1). The inferred intrinsic luminosity is 5.7×10^{43} ergs s^{-1}, which is similar to that of other non-quasar AGN. The source was observed twice, and showed consistent fluxes, with ROSAT HRI in June 1992 and May 1993 respectively. However, the brightness decreased by 30% from the later HRI observation to the PSPC observation which was taken one week apart. These factors suggest the source is variable and thus there might be non-thermal origin for the X-ray flux.

A simple power-law model fails to well describe the ASCA data, mainly due to an abnormal excess absorption above the Galactic value is required. Consider that this excess absorption might be an artifact due to a false spectral model, we next fitted the data with a broken power-law with free break energy. Thus the fit to the data is notablely improved at a $\sim 90\%$ level, yields the absorption in consistent with the Galactic value and two powerlaw components with a break-point at ~ 2.1 keV (see Table 1). The lower-energy part is flatter with a slope in good agreement with that of ROSAT spectrum; the higher-energy part is steeper with $\Gamma = 2.6^{+0.3}_{-0.3}$.

Comparison with the ROSAT/PSPC observation, the ASCA data indicate that the source brightness decreased by 33% in the 0.1–2.4 keV band in a 1.5 years interval. Meanwhile the broad-band X-ray spectrum remained the shape at the

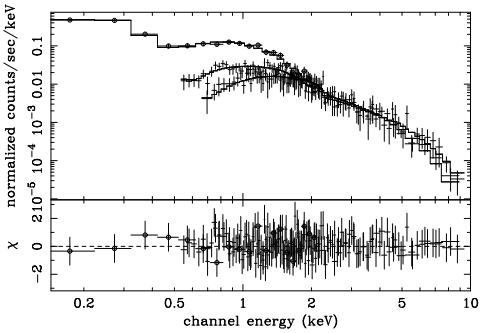

Figure 1. Folded ROSAT/PSPC and ASCA SIS/GIS spectra of PKS 2316-423.

Table1. Spectral fitting (with 90% errors).

Data	$N_{\rm H}$ $[10^{20}$ cm$^{-2}]$	Γ_1	χ^2_ν/d.o.f.
ROSAT	$1.4^{+0.5}_{-0.4}$	$2.0^{+0.2}_{-0.2}$	1.1/17
ASCA	$2.2^{+2.2}_{-2.0}$	$2.0^{+0.4}_{-0.2}$	1.0/131

Γ_2	$E_{\rm break}$ keV	$F^{obs}_{0.1-2{\rm keV}}$ $(10^{-12}$ergs cm^{-2} s$^{-1})$
–	–	$2.63^{+0.15}_{-0.18}$
$2.6^{+0.3}_{-0.3}$	2.1	$1.35^{+0.33}_{-0.20}$

lower-energy part, and hardened the slope in higher-energy range, which was likely in a manner of the prediction of the synchrotron radiation losses.

3. SPECTRAL ENERGY DISTRIBUTION

The composite SED (Figure 2), from both space and ground-based observations, provides further insights into the object. It is clear that the SED from radio to X-ray is possibly from only one radiation component (Synchrotron emission) and peaks at a higher frequency falling in the EUV/soft-X-ray band ($\nu_p = 7.3 \times 10^{15}$ Hz). The optical and ultraviolet radiation appear to be a continuation of the radio synchrotron spectrum; the X-ray data are likely from a common emission origin as the lower energy parts and represents a high energy tail of the synchrotron spectrum. Other relevant slope parameters from the SED are listed in Table 2.

For a comparison, we plotted in Figure 2 the EGRET sensitivity threshold as an upper limit to the GeV flux (marked by an arrow), since the source was never detected at γ-ray. It is shown that the source is well dominated by a synchrotron process.

4. DISCUSSIONS

Putting 2316-423 on the α_{ro} vs α_{ox} color-color diagram, we find it is in the intermediate range of BL Lacs. As we know, α_{XOX} can more precisely measure spectral changes from optical to soft X-ray bands, however, the values of α_{XOX} for PKS 2316-423 depend on the assumption of the X-ray spectral indices, being 0.18/0.26 and -0.42/-0.34 for $\alpha_x = 1.0$ and 1.6, respectively. These values should locate in the intermediate range of the α_{XOX} distribution of recent BL Lacs samples (Laurent-Muehleisen et al. 1999).

The importance of the frequency at which the synchrotron radiation peaks is that it provides a powerful diagnostics for the physical condition of the emitting region. Recent studies showed that among BL Lacs the synchrotron peak frequencies are inversely correlated with their luminosities (Fossati et al. 1998). We could put

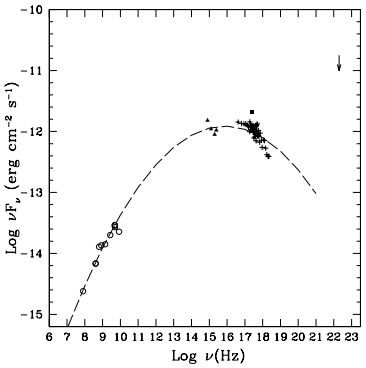

Table 2. Broad-band slopes of SED

α_{ro}	α_{ox}	α_x (0.1-2 keV)	α_x (2-10 keV)
0.56	1.18/1.26	1.0	1.6

Figure 2. The multifrequency SED of PKS 2316-423 and its parabolic fit. The X-ray points are data from this paper, plotted with solid squares for ROSAT/HRI and cross marks for ASCA and ROSAT/PSPC. The UV/optical points are data from Crawford and Fabian (1994) plotted with solid triangle. Circle symbols represent radio data from NASA/IPAC Extra-galactic Database (NED).

PKS 2316-423 on the Figure 7c of Fossati et al. (1998). Due to its lowest peak luminosity, PKS 2316-423 should locate the right-bottom end, this means that the peak frequency of PKS 2316-423 would be around $\sim 10^{18}$ Hz, however, our fit to the SED just gives $\nu_p \sim 10^{16}$ Hz. Therefore, we suggest that PKS 2316-423 might be a low luminosity "intermediate" object between HBLs and LBLs.

In a summary, the X-ray spectral and SED analysis of PKS 2316-423 point out its IBL or HBL attributes with very low luminosity compared with the most recent BL Lac samples. Because of its peculiar low luminosity, however, the more detailed studies of PKS 2316-423 will shed light on the evolution of BL Lac objects.

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